

CLAIMS

What is claimed:

1. A suspension assembly for an actuator element of a
5 microelectromechanical system, said suspension assembly being disposed on a
base substrate, wherein said suspension assembly comprises:

a support structure interconnected with said base substrate and
comprising a medial support rail and a plurality of support beams extending out from
first and second lateral sides of said medial support rail;

10 an intermediate actuation structure interconnected with said support
structure and disposed between said support structure of said suspension assembly
and said base substrate of said microelectromechanical system;

a first linkage structure operatively interposed between said base
substrate and said support structure; and

15 a second linkage structure operatively interposed between said
support structure and said intermediate actuation structure.

2. A suspension assembly, as claimed in Claim 1, wherein said
first linkage structure enables at least part of said support structure to move relative
20 to said base substrate.

3. A suspension assembly, as claimed in Claim 1, wherein said second linkage structure enables said intermediate actuation structure to move relative to at least one of said support structure and said base substrate.

5 4. A suspension assembly, as claimed in Claim 1, wherein said actuator element is interconnected to said intermediate actuation structure.

10 5. A suspension assembly, as claimed in Claim 1, wherein said actuator element is connected to said intermediate actuation structure such that said actuator element and said support structure are substantially coplanar.

6. A suspension assembly, as claimed in Claim 1, wherein said actuator element comprises an electrostatic comb.

15 7. A suspension assembly, as claimed in Claim 1, wherein said base substrate comprises a voltage reference plane.

20 8. A suspension assembly, as claimed in Claim 1, wherein said support beams have distal ends remotely disposed from said medial support rail, and wherein distal ends of said support beams are connected to said base substrate via linkages of said first linkage structure.

9. A suspension assembly, as claimed in Claim 1, wherein said first linkage structure comprises at least three layers of polysilicon.

10. A suspension assembly, as claimed in Claim 1, wherein said intermediate actuation structure comprises a central actuation rail and a plurality of actuation beams extending out from said central actuation rail.

11. A suspension assembly, as claimed in Claim 10, wherein said actuation beams have peripheral ends remotely disposed from said central actuation rail, and wherein peripheral ends of said actuation beams are connected to said support structure via said second linkage structure.

12. A suspension assembly, as claimed in Claim 1, wherein said second linkage structure comprises at least one layer of polysilicon.

13. A suspension assembly, as claimed in Claim 1, wherein said intermediate actuation structure only interconnects with said base substrate via said support structure.

14. A suspension assembly, as claimed in Claim 1, wherein said intermediate actuation structure avoids direct contact with said base substrate.

15. A suspension assembly, as claimed in Claim 1, wherein said intermediate actuation structure is suspended over said base substrate due to said second linkage structure connecting said intermediate actuation structure to said support structure.

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16. A suspension assembly, as claimed in Claim 1, wherein said intermediate actuation structure can be displaced by a first distance, and wherein said support structure is displaced by a second distance less than said first distance when said intermediate actuation structure is displaced by said first distance.

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17. A suspension assembly, as claimed in Claim 1, wherein said intermediate actuation structure comprises at least one linkage channel, and wherein at least a portion of said first linkage structure passes through said at least one linkage channel so as to enable said intermediate actuation structure to move without interference from said first linkage structure.

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18. A suspension assembly, as claimed in Claim 17, wherein said at least one linkage channel is oblong or elliptical.

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19. A suspension assembly, as claimed in Claim 1, wherein said intermediate actuation structure comprises first and second lateral actuation rails which are substantially parallel to a direction of movement of said intermediate actuation structure.

20. A suspension assembly, as claimed in Claim 19, wherein said intermediate actuation structure comprises at least one actuation beam connecting said first lateral actuation rail to said second lateral actuation rail.

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21. A suspension assembly, as claimed in Claim 19, wherein said intermediate actuation structure comprises a central actuation rail disposed between said first and second lateral actuation rails.

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22. A suspension assembly, as claimed in Claim 21, wherein said intermediate actuation structure comprises a plurality of actuation beams connecting said first and second lateral actuation rails to said central actuation rail.

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23. A suspension assembly, as claimed in Claim 22, wherein at least one actuation beam of said plurality of actuation beams perpendicularly interfaces with at least one of said first lateral actuation rail, said second lateral actuation rail, and said central actuation rail.

24. A suspension assembly for an actuator element of a microelectromechanical system, wherein said suspension assembly comprises:

a first support structure interconnected with a base of said microelectromechanical system;

5 a second support structure interconnected with said first support structure; and

an intermediate actuation structure interconnected with said actuator element and operatively interposed between and interconnected with said first support structure and said second support structure,

10 wherein at least one of said first and second support structures comprises a longitudinal center support beam comprising elongate first and second lateral sides, and wherein said longitudinal center support beam comprises a plurality of arms connected to and extending out from said first and second lateral sides of said center support beam.

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25. A suspension assembly, as claimed in Claim 24, further comprising a plurality of base anchors connecting said first support structure to said base.

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26. A suspension assembly, as claimed in Claim 24, further comprising a plurality of support anchors disposed between and interconnecting said first support structure and said intermediate actuation structure.

27. A suspension assembly, as claimed in Claim 24, further comprising a plurality of support anchors disposed between and interconnecting said intermediate actuation structure and said second support structure.

5 28. A suspension assembly, as claimed in Claim 24, wherein said first support structure comprises said center support beam, and wherein said plurality of arms comprises first, second, third, and fourth lower support arms interconnected with said center support beam and at least first and second lower flex arms interconnected with said center support beam, wherein said first and second
10 lower support arms and said first lower flex arm are disposed on said first lateral side of said center support beam, and wherein said third and fourth lower support arms and said second lower flex arm are disposed on said second lateral side of said center support beam.

15 29. A suspension assembly, as claimed in Claim 28, wherein said first lower flex arm is disposed between said first and second lower support arms.

 30. A suspension assembly, as claimed in Claim 28, wherein said second lower flex arm is disposed between said third and fourth lower support arms.

20 31. A suspension assembly, as claimed in Claim 28, wherein said first lower flex arm is substantially aligned with said first and second lower support

arms, and wherein said second lower flex arm is substantially aligned with said third and fourth lower support arms.

32. A suspension assembly, as claimed in Claim 28, wherein first,
5 second, third, and fourth fixed ends of respective said first, second, third, and fourth lower support arms are remotely disposed from said center support beam.

33. A suspension assembly, as claimed in Claim 32, wherein first,
second, third, and fourth fixed ends of respective said first, second, third, and fourth
10 lower support arms are interconnected with said base.

34. A suspension assembly, as claimed in Claim 28, wherein an
entirety of each of said first and second lower flex arms is separated from and
avoids direct contact with said base so that said first and second lower flex arms are
15 substantially unimpeded by any interconnection of said first and second lower flex
arms to said base.

35. A suspension assembly, as claimed in Claim 28, wherein first
and second free ends of respective said first and second lower flex arms are
20 remotely disposed from said center support beam.

36. A suspension assembly, as claimed in Claim 28, wherein first and second free ends of respective said first and second lower flex arms are separated from and avoids direct contact with said base.

5 37. A suspension assembly, as claimed in Claim 28, further comprising a plurality of base anchors connecting first, second, third, and fourth fixed ends of respective said first, second, third, and fourth lower support arms of said first support structure to said base.

10 38. A suspension assembly, as claimed in Claim 28, further comprising third and fourth lower flex arms interconnected with said center support beam.

15 39. A suspension assembly, as claimed in Claim 38, wherein third and fourth free ends of respective said third and fourth lower flex arms are remotely disposed from said center support beam.

20 40. A suspension assembly, as claimed in Claim 38, wherein third and fourth free ends of respective said third and fourth lower flex arms are separated from said base.

41. A suspension assembly, as claimed in Claim 24, wherein said intermediate actuation structure comprises a central actuator beam interconnected with displacement multiplier.

5 42. A suspension assembly, as claimed in Claim 24, wherein said intermediate actuator structure comprises a central actuator beam interconnected with an elevator assembly for positioning a microstructure.

10 43. A suspension assembly, as claimed in Claim 24, wherein said intermediate actuator structure comprises a central actuator beam parallel to and vertically spaced from said center support beam.

15 44. A suspension assembly, as claimed in Claim 43, wherein said central actuator beam comprises laterally extending actuator arms.

45. A suspension assembly, as claimed in Claim 44, wherein said actuator element is connected to at least one of said laterally extending actuator arms.

20 46. A suspension assembly, as claimed in Claim 24, wherein said second support structure comprises said center support beam, and wherein said plurality of arms comprises first, second, third, and fourth upper support arms interconnected with said center support beam and at least first and second upper

flex arms interconnected with said center support beam, wherein said first and second upper support arms and said first upper flex arm are disposed on said first lateral side of said center support beam, and wherein said third and fourth upper support arms and said second upper flex arm are disposed on said second lateral
5 side of said center support beam.

47. A suspension assembly, as claimed in Claim 46, wherein said first upper flex arm is disposed between said first and second upper support arms.

10 48. A suspension assembly, as claimed in Claim 46, wherein said second upper flex arm is disposed between said third and fourth upper support arms.

15 49. A suspension assembly, as claimed in Claim 46, wherein said first upper flex arm is substantially aligned with said first and second upper support arms, and wherein said second upper flex arm is substantially aligned with said third and fourth upper support arms.

20 50. A suspension assembly, as claimed in Claim 46, wherein first, second, third, and fourth fixed ends of respective said first, second, third, and fourth upper support arms are remotely disposed from said center support beam.

51. A suspension assembly, as claimed in Claim 50, wherein first, second, third, and fourth fixed ends of respective said first, second, third, and fourth upper support arms are interconnected with said first support structure.

5 52. A suspension assembly, as claimed in Claim 51, wherein an entirety of each of said first and second upper flex arms is separated from and avoids direct contact with said base so that said first and second upper flex arms are substantially unimpeded by any interconnection of said first and second upper flex arms to said base.

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53. A suspension assembly, as claimed in Claim 46, wherein first and second free ends of respective said first and second upper flex arms are remotely disposed from said center support beam.

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54. A suspension assembly, as claimed in Claim 46, wherein first and second free ends of respective said first and second upper flex arms are separated from and avoid direct contact with said base.

20 55. A suspension assembly, as claimed in Claim 46, further comprising a plurality of upper support anchors interconnecting first, second, third, and fourth fixed ends of respective said first, second, third, and fourth upper support arms of said second support structure to said first support structure.

56. A suspension assembly, as claimed in Claim 46, further comprising third and fourth upper flex arms interconnected with said center support beam.

5 57. A suspension assembly, as claimed in Claim 56, wherein third and fourth free ends of respective said third and fourth upper flex arms are remotely disposed from said center support beam.

58. A suspension assembly, as claimed in Claim 56, wherein third
10 and fourth free ends of respective said third and fourth upper flex arms are separated from said base.

59. A suspension assembly, as claimed in Claim 24, wherein at
least portions of said second support structure are substantially parallel to and
15 vertically spaced from said first support structure.

60. A suspension assembly, as claimed in Claim 24, wherein only
one of said first and second support structures comprises first and second center
support rails, wherein said first and second center support rails are substantially
20 parallel to and vertically spaced from said center support beam.

61. A suspension assembly, as claimed in Claim 60, wherein said first center support rail is laterally spaced from and substantially parallel to said second center support rail.

5 62. A suspension assembly, as claimed in Claim 24, wherein each of said first and second support structures comprise a center support beam.

63. A suspension assembly, as claimed in Claim 62, wherein said first support structure comprises a first plurality of arms, wherein said second
10 support structure comprises a second plurality of arms, and wherein said first plurality of arms is vertically spaced from and substantially parallel to said second plurality of arms.

64. A suspension assembly, as claimed in Claim 24, wherein said
15 suspension assembly is made from a structural material comprising a tensile strength of at least about 0.25 GPa.

65. A suspension assembly, as claimed in Claim 24, wherein said base is a silicon wafer.

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66. A suspension assembly, as claimed in Claim 24, wherein said base comprises a voltage reference plane.

67. A suspension assembly, as claimed in Claim 24, wherein at least one of said first support structure, said intermediate actuation structure, and said second support structure is formed from polysilicon.

5 68. A suspension assembly, as claimed in Claim 24, wherein said actuator element comprises an electrostatic comb.

69. A suspension assembly for at least assisting in supporting a first actuation element of a microelectromechanical system and allowing movement of said first actuation element of a microelectromechanical system relative to a base substrate, wherein said suspension assembly comprises:

5 a longitudinal support beam comprising elongate first and second lateral sides; and

a plurality of first lateral beams extending out from said first and second lateral sides of said support beam, wherein at least one of said first lateral beams is anchored to said base substrate.

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70. A suspension assembly, as claimed in Claim 69, wherein said first lateral beams are oriented in a substantially perpendicular relationship with respect to said support beam.

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71. A suspension assembly, as claimed in Claim 69, wherein said at least one of said first lateral beams comprises a fixed end disposed most remote from said support beam, wherein said fixed end is anchored to said base substrate.

20 72. A suspension assembly, as claimed in Claim 69, wherein ones of said first lateral beams are vertically spaced from and devoid of any anchoring to said base substrate.

73. A suspension assembly, as claimed in Claim 69, wherein said plurality of said first lateral beams is anchored to said base substrate.

74. A suspension assembly, as claimed in Claim 73, wherein said
5 first lateral beams comprise fixed ends disposed most remote from said support beam, and wherein said fixed ends are anchored to said base substrate.

75. A suspension assembly, as claimed in Claim 73, further comprising a plurality of second lateral beams.

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76. A suspension assembly, as claimed in Claim 75, wherein said second lateral beams are oriented in a substantially perpendicular relationship with respect to said support beam.

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77. A suspension assembly, as claimed in Claim 75, wherein said second lateral beams are oriented in substantially parallel relationship with respect to said first lateral beams.

78. A suspension assembly, as claimed in Claim 75, wherein each
20 of said second lateral beams comprises a free end, and wherein each said free ends is vertically spaced from and devoid of any anchoring to said base substrate.

79. A suspension assembly, as claimed in Claim 69, further comprising an actuation assembly, wherein said actuation assembly comprises a plurality of actuation beams oriented substantially parallel to said support beam and interconnected with ones of said plurality of said first lateral beams.

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80. A suspension assembly, as claimed in Claim 79, wherein said actuation assembly is vertically displaced from said support beam.

81. A suspension assembly, as claimed in Claim 79, wherein said
10 first actuation element is interconnected to at least one of said actuation beams.

82. A suspension assembly, as claimed in Claim 79, wherein said actuation assembly comprises a plurality of second lateral beams oriented substantially perpendicular to said plurality of said actuation beams and extending
15 between and interconnecting at least ones of said plurality of said actuation beams.

83. A suspension assembly, as claimed in Claim 82, wherein said first actuation element is interconnected to at least one of said plurality of said second lateral beams.

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84. A suspension assembly, as claimed in Claim 79, further comprising a support assembly, wherein said support assembly comprises a first central beam and a second central beam adjacent to said first central beam and a

plurality of third and fourth lateral beams extending out from said first and second central beams.

85. A suspension assembly, as claimed in Claim 84, wherein said
5 plurality of said third lateral beams are interconnected with said plurality of said first lateral beams.

86. A suspension assembly, as claimed in Claim 84, wherein said
plurality of said fourth lateral beams are interconnected with said plurality of said first
10 lateral beams.

87. A suspension assembly, as claimed in Claim 86, wherein said
plurality of said actuation beams of said actuation assembly are disposed between
and interconnected with said plurality of said first lateral beams and said plurality of
15 said fourth lateral beams.